

THE EFFECTS OF DIMENSIONAL ANALYSIS
ON THE MEDICATION DOSAGE CALCULATION ABILITIES
OF NURSING STUDENTS

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by
Gloria P. Craig, R.N., B.S.N.
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Approved by Committee:

<u>Sandra L. Sellers</u>	<u>11/9/93</u>
Sandra L. Sellers, Ph.D., R.N.	Date
<u>Mary C. Hansen</u>	<u>11-9-93</u>
Mary C. Hansen, Ph.D., R.N.	Date
<u>Richard J. Morrow</u>	<u>11/9/93</u>
Richard J. Morrow, Ph.D.	Date

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ABSTRACT

The purpose of this study was to examine if the use of the problem-solving method of dimensional analysis would improve the medication dosage calculation abilities of nursing students. To investigate the effectiveness of dimensional analysis, a quasi-experimental research study was designed. The 59 nursing students participating in the study included an experimental group of 30 nursing students from a diploma nursing program and a control group of 29 nursing students from an associate nursing program located in central Iowa.

Two research hypotheses were proposed for this study. The first research hypothesis was: Nursing students in the experimental group who are taught dimensional analysis will demonstrate significantly greater improvement in the medication calculation pretest/post-test scores than nursing students in the control group. This hypothesis was supported ($t=4.96$, $p=.00001$).

The second research hypothesis was: Nursing students in the experimental group who are taught dimensional analysis will have higher scores on the medication calculation post-test than the nursing students in the control group. This hypothesis was not supported ($t=-.77$, $p=.78$).

An additional finding was a slightly inverse relationship with the number of steps and conversions in each problem when correlated with the number of correct responses on the post-test for the experimental group (steps/ $r=-0.476$, conversions/ $r=-0.340$), control group (steps/ $r=-0.238$, conversions/ $r=-0.151$), and both groups combined (steps/ $r=-0.371$, conversions/ $r=-0.253$).

Another finding demonstrated that there was a significant difference between the pretest scores of the experimental and control groups ($t=-5.55$, $p=.00001$). This was somewhat expected based on the chemistry and mathematical differences revealed on the demographic tool.

The literature identified that dosage calculation deficiencies are a problem within the nursing discipline. The findings of this study are significant in that they support the use of dimensional analysis as an avenue to be considered when the goal is improvement of medication dosage calculation abilities. A recommendation from this study is the use of dimensional analysis as a consistent problem-solving method for teaching medication dosage calculation to all levels of nursing students.

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CHAPTER ONE INTRODUCTION

Overview of the Problem

Every nurse must know and practice the five rights of drug administration: the right drug, the right dose, the right route, the right time, and the right patient. Although nurses may be able to identify the right drug, route, time, and patient, the right dose requires mathematical, conceptual, and cognitive skills that may pose difficulty for some individuals.

With a convenience sample of 110 subjects, Bindler and Bayne (1991) identified in a descriptive study that 81% of the registered nurses surveyed in four western states were unable to calculate medication doses at a 90% level of proficiency on a 20-item medication calculation test. In addition, they found that 43.6% of the test scores were below the 70% level. The investigators suggested that this unsatisfactory performance level should be a major concern for nurse educators and proposed that the most effective way to improve the mathematical calculation abilities of registered nurses would be to incorporate a specific problem-solving methodology into nursing curricula.

Nursing education programs attest that they graduate safe, first line practitioners. Some researchers asserted, however, that this may be a misconception (Bindler and Bayne, 1991). In a previous descriptive study conducted by Bindler and Bayne (1984), the basic mathematical skills of 741 baccalaureate nursing students were tested. Bindler and Bayne identified that the junior nursing students in the sample were unable to pass from 9% to 38% of the six parts of the Mathematics Proficiency Exam at a 70% proficiency level. The authors concluded that a substantial number of the nursing students did not possess the basic mathematical abilities necessary to function as registered nurses. They strongly recommended that schools of nursing take an active role in identifying these students and finding methods to improve their mathematical abilities.

No research studies regarding methods for improving mathematical abilities of nursing students were identified in the nursing literature. There were, however, research studies and methods suggested in the educational literature of another discipline. Goodstein (1983) established that a majority of chemistry students were deficient in their ability to deal with the quantitative aspects of the subject matter. In an effort to improve the quantitative abilities of chemistry students, the chemistry educators utilized

a problem-solving method called dimensional analysis (also called factor label method, conversion-factor method, units analysis, and quantity calculus). Goodstein expressed that even though the ratio-proportion method was at one time the primary problem-solving method, it has been largely replaced by a dimensional analysis approach in most introductory chemistry textbooks.

Dimensional analysis was identified in chemistry textbooks as a problem-solving method as early as 1938. Frey (1938) defined dimensional analysis but did not specifically explain how this method could be used to solve chemistry problems. Johnson (1969) defined dimensional analysis and described why this problem-solving method should be used to solve chemistry problems. He did not explain, however, how this method could be used to solve chemistry problems. Goodstein (1983) described dimensional analysis as a problem-solving method that is very simple to understand, reduces errors and requires less conceptual reasoning power to understand than does the ratio-proportion method. She stated that this method condenses multi-step problems into one orderly extended solution.

Hein (1983) described dimensional analysis as a useful method for solving a variety of chemistry, physics, mathematics, and daily life problems. He identified that

dimensional analysis is often the problem-solving method of choice because it provides a systematic, straightforward way to set up problems; gives a clear understanding of the principles of the problem; helps the learner to organize and evaluate data; and assists in identifying errors in that unwanted units are not eliminated if the setup of the problem is incorrect.

Peters (1986) identified dimensional analysis as a method used for solving not only chemistry problems but also a variety of other mathematical problems that require conversions. He described dimensional analysis as a method that can be used whenever two quantities are directly proportional to each other and one quantity must be converted to the other using a conversion factor or conversion relationship. Once the given quantity needed is identified, the unit path (the series of unit conversions necessary to achieve the answer) is established. Peters (1986, pp. 25-31) summarized the problem-solving method of dimensional analysis as follows:

Problem: 3 yards = How many inches?

1. Begin with the given quantity.

Example: 3 yards

2. Establish the unit path from the given quantity to the wanted quantity, selecting the equations which will be used as conversion factors.

Example: 1 yard = 3 feet

Example: 1 foot = 12 inches

3. Write the setup for the problem, multiplying and dividing in a logical sequence through each step of the unit path.

Given quantity x (One or more conversion factors)
= Wanted quantity.

Example: 3 yards = How many inches?

$$3 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}} =$$

Note that every conversion factor is a ratio of units which equals 1.

4. Cancel units to be certain that the setup gives an answer expressed in the correct units. Yards cancel. Feet cancel. Inches remain as the desired unit.

$$\text{Example: } 3 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}} =$$

5. Multiply the numerators, multiply the denominators and divide the product of the numerators by the product of the denominators to provide the numerical value of the answer.

Example: 3 yards x 3 feet x 12 inches = 108 inches
 1 yard 1 foot

The nursing literature has identified that many nurses experience difficulty in calculating medication doses. Chemistry educators have adopted a method that is not only easier to learn but also reduces errors when some type of mathematical conversion is required. Nurse educators should be interested in the use of dimensional analysis as a method to improve the mathematical abilities of their students. Ultimately, this improved methodology might well reduce the medication errors that occur within the discipline of nursing.

Purpose of the Study

The purpose of this study was to examine if the use of the problem-solving method of dimensional analysis would improve the medication dosage calculation abilities of nursing students. Specifically, the study examined the problem solving competence of diploma nursing students who were taught to perform medication calculations using dimensional analysis as compared to the problem solving competence of associate degree nursing students taught medication calculations by the traditional problem-solving methodologies.

Research Hypotheses

The research hypotheses for this study were:

1. Nursing students in the experimental group who are taught dimensional analysis will demonstrate significantly greater improvement in the medication calculation pretest/post-test scores than nursing students in the control group.
2. Nursing students in the experimental group who are taught dimensional analysis will have higher scores on the medication calculation post-test than the nursing students in the control group.

Definition of Terms

The terms used for this study were defined as follows:

Experimental group - Experimental group was defined as those nursing students enrolled in the second level or second year of a diploma nursing program who were taught to use dimensional analysis to calculate medication problems.

Control group - Control group was defined as nursing students enrolled in the second level or second year of an associate nursing program who were instructed in the use of ratio-proportion or desired dose/dose on hand to calculate medication problems.

Dimensional analysis - Dimensional analysis was defined as a problem-solving method that can be used to calculate medication dosage problems whenever two quantities are directly proportional to each other and one quantity must be converted to the other using a conversion factor or conversion relationship.

Nursing students - Nursing students were defined as those students enrolled in the second level or second year of a two-year associate degree nursing program or of a three-year diploma nursing program located in central Iowa.

Medication calculation pretest/post-test - The medication calculation pretest/post-test consisted of a researcher-developed, 20-item medication calculation test containing a variety of problems that a registered nurse would encounter with medication administration in clinical nursing practice.

Improvement - Improvement was defined as a higher total score on the medication calculation post-test when compared with the total score on the medication calculation pretest for each group.

Scores - Scores were defined as the number of correct answers scored on the 20-item medication calculation pretest/post-test.

Overview of the Theoretical Framework

According to cognitive theory, learning is dependent on how information is structured, organized and conceptualized. It involves associations established according to the principles of contact and repetition. Learning is viewed as involving the acquisition or reorganization of cognitive structures through which humans process and store information. The items of information acquired through learning are sorted, filed, and cross-indexed. This allows for meaningful learning and retaining of information in an organized fashion (Good and Brophy, 1986). Dimensional analysis is a problem-solving approach that is based on cognitive theory.

Significance to Nursing

Two studies regarding mathematical abilities or the lack of mathematical abilities of registered nurses have suggested that nurse educators should be concerned about the mathematical skills of practitioners (Bindler and Bayne, 1991; 1984). Although these studies were performed by the same researchers, the time span demonstrates that after seven years the problem with the lack of mathematical skills of nurses continued and had not improved.

Other studies also have identified factors that affect the mathematical calculation abilities of nurses. Worrell

and Hodson (1989) proposed and verified that inconsistencies between teaching methodologies of nursing faculty members and the use of different formulas have a negative effect on nursing students' mathematical calculation abilities. Whereas, some nurse educators may use the ratio-proportion problem solving method, others may use a different method creating confusion among students required to perform calculations with multi-step methods.

In addition to the two major studies that have evaluated nursing students' computational abilities (Bayne and Bindler, 1988; Worrell and Hodson, 1989), other studies have been conducted that also have identified that the difficulty with mathematical calculations seems to be the students' problem-solving abilities as opposed to computational skills (Blais and Bath, 1992; Chenger, Conklin, Hirst, Reimer, and Watson, 1988). Blais and Bath (1992) recommended that educators teach a method of problem solving that will allow students to conceptualize the problem by setting up their mathematical problems in a neat and organized manner that shows the flow of problem solving.

The literature identifies that mathematical and dosage calculation deficiencies continue to be a problem within the nursing discipline. Calculation deficiencies among

nurses or nursing students lead to medication errors that threaten patient safety and are costly in terms of malpractice litigation. Research is needed to evaluate alternative methods of teaching nurses and nursing students to calculate medication problems that arise in clinical nursing practice. Chemistry educators have identified and adopted dimensional analysis as an effective method that allows students to solve difficult problems involving conversions. To this date, however, no formal research has been conducted to ascertain whether nursing students who are taught dimensional analysis will be more accurate in calculating medication problems that require some type of conversion. Because mathematical and dosage calculation deficiencies are a problem, this quasi-experimental research study was conducted to evaluate an alternative method of teaching nursing students to calculate medication problems through the use of the previously established successful method of dimensional analysis.

CHAPTER TWO REVIEW OF THE LITERATURE

The purpose of this study was to examine if the use of the problem-solving method of dimensional analysis would improve the medication dosage calculation abilities of nursing students. This chapter is divided into three sections. The first section describes the theoretical framework used as the theoretical foundation for the study. The second section discusses research studies relevant to the study. The chapter concludes with a summary of the literature review.

Theoretical Framework

This study researched the use of the problem-solving method of dimensional analysis by nursing students to improve medication calculation abilities. Goodstein (1983) described dimensional analysis as a problem-solving method that is very simple to understand; reduces errors; requires less conceptual reasoning power to understand than other methods; and condenses multi-step problems into one orderly extended solution. Hein (1983) identified that dimensional analysis provides a systematic, straightforward way to set up problems; gives a clear understanding of the principles of the problem; helps the learner to organize and evaluate data; and assists in identifying errors in

that unwanted units are not eliminated if the setup of the problem is incorrect. Peters (1986) described dimensional analysis as a method that can be used whenever two quantities are directly proportional to each other and one quantity must be converted to the other utilizing a conversion factor or conversion relationship. After the given quantity needed is identified, the unit path (the series of unit conversions necessary to achieve the answer) is established.

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Example: 1 yard = 3 feet

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3. Write the setup for the problem, multiplying and dividing in a logical sequence through each step of the unit path.

Given quantity x (One or more conversion factors) = Wanted quantity.

Example: 3 yards = How many inches?

$$3 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}} =$$

Note that every conversion factor is a ratio of units which equals 1.

4. Cancel units to be certain that the setup gives an answer expressed in the correct units. Yards and feet can be canceled from the problem because they are represented in both the top portion of the problem (numerator) and the bottom portion of the problem (denominator) leaving inches to provide the numerical value of the answer.

$$\text{Example: } 3 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}} =$$

5. Multiply the numerators, multiply the denominators and divide the product of the numerators by the product of the denominators to provide the numerical value of the answer.

$$\text{Example: } 3 \text{ yards} \times \frac{3 \text{ feet}}{1 \text{ yard}} \times \frac{12 \text{ inches}}{1 \text{ foot}} = 108 \text{ inches}$$

The concept of the problem-solving method of dimensional analysis is based on cognitive theory. In 1960, Bruner theorized that learning is dependent on how information is structured, organized, and conceptualized.

He proposed a cognitive learning model that emphasizes the acquisition, organization (structure), understanding, and transfer of knowledge - focusing on "how" to learn, rather than "what" to learn. He purported that stimulus input received is actively perceived and interpreted in an organized fashion, using expectations developed from prior experiences.

Bruner (1966) viewed learning as an ongoing process of developing a cognitive structure for representing and interacting with new information. According to one of his principles of cognitive development, learning is possible because events are internalized into a "storage system" that amounts to an organized model. This "storage system" stores the information perceived and interpreted in the form of imagery, concepts, and other representational structures. This "storage system" allows new information to be predicted and learned (Bruner, 1966, p. 5).

Another principle of cognitive learning proposed by Bruner (1966) involves the increasing ability to verbalize to oneself or others, using words or symbols, what one has done or will do which creates the ability to solve problems through analytic thinking. Analytic thinking was defined by Bruner (1960) as the ability to precede a step at a time with explicit steps that can be adequately

reported by the thinker to another individual.

According to cognitive theory, therefore, learning is dependent on how information is structured, organized, and conceptualized. It involves associations established according to the principles of contiguity and repetition. Learning is viewed as involving the acquisition or reorganization of the cognitive structures through which humans process and store information. The items of information acquired through learning are stored, filed, and cross-indexed. This allows for meaningful learning and retention of information in an organized fashion (Good and Brophy, 1986).

Dimensional analysis is a problem-solving method that is based on the principles of cognitive theory. Hein (1983) identified that dimensional analysis provides a systematic straightforward way to set up problems and helps to organize and evaluate data that correlates with the "storage system" described by Bruner. Hein also emphasized that dimensional analysis gives a clear understanding of the principles of the problem correlating with the ability to verbalize what steps are taken leading to analytic thinking as identified by Bruner.

Related Literature

Although much has been written for decades about the serious problem of medication errors, the dilemma persists. As early as 1979, Perlstein, Callison, White, Barnes and Edwards conducted a study to identify the number of errors in the drug dosage computations by personnel employed in newborn intensive care units. Five pharmacists, 11 pediatricians, and 27 nurses who worked in a newborn intensive care unit were tested for accuracy in calculating drug doses. The testing instrument was comprised of ten problems including the physician's order, the weight of the infant and the concentration of the drug in stock. The study included only those errors that were at least 10 times greater or 10 times less than the prescribed dosage. The pharmacists received a mean test score of 96% with a range of 85% to 100%; the pediatricians received a mean test score of 89.1% with a range of 80% to 100%; and the nurses received the lowest mean test score of 75.6% with a range of 45% to 95%.

A second study, conducted by Perlstein et al. in 1979, focused only on those serious medication computational errors that might result in increased morbidity or mortality. The study included a total of 95 registered nurses (31 experienced nurses with more than one year of

professional experience and 64 inexperienced nurses with less than one year of experience since graduation from nursing school). The same ten-problem testing instrument was used for this study with the 31 experienced nurses receiving a mean test score of $88.1\% \pm (SE) 1.7$ which was not significantly different from the mean test score of $85.1\% \pm (SE) 1.4$ received by the 64 inexperienced nurses ($p < .05$).

The researchers (Perlstein et al., 1979) identified from the results of the studies that the most frequent computational errors involved misplacement of decimal points, careless and unclear writing that resulted in the inability to correctly identify the answer, and the lack of following ordered mechanisms of computation (figuring the problem mentally without use of a visual formula). Although hospitals have attempted to reduce medication errors by using the unit dose system, this system is not applicable for the newborn intensive care unit because doses are calculated according to weight, age, and gestation that are constantly changing variables. The study concluded that those responsible for the education of health care professionals should not assume that everyone is proficient in arithmetic skills and that remedial assistance may be needed.

Dexter and Applegate (1980) identified that the nursing students in an associate degree nursing program at Indiana University were deficient in mathematical skills. They suggested that even in the face of less hands-on involvement brought on by adoption of the unit dose system, use of calculators or preparation of intravenous medications by pharmacy, the nurse maintains legal responsibility for medication administration. They established several guidelines to improve the mathematical skills of nursing students. These guidelines included administering a mathematical quiz at the beginning of each module of the nursing program to measure and reinforce retention of previous learning; requiring 90% proficiency on mathematical quizzes consistently throughout the nursing curriculum; utilizing study guides with clear objectives and practice problems; and requesting consistency by the nursing faculty to reinforce the method of calculation (ratio-proportion method) that the students were originally taught. Although no statistical data were provided regarding the numbers involved in the study, the initial findings demonstrated a 5.7% increase in the dosage calculation test scores for the first group of nursing students in the new system.

Ptaszynski and Silver (1981) identified that the problem of poor calculation skills exists in other nursing programs. They found that nursing students entering baccalaureate nursing programs also have difficulty with dosage calculation complicated by a decline in SAT scores and varying degrees of mathematical background. They speculated that given these two variables along with the unit dose system used for medication administration, the problem of poor calculation skills is only compounded.

In an attempt to rectify the situation, Ptaszynski and Silver (1981) introduced posology (the study of dosage calculations) in an orderly, systematic fashion into an integrated curriculum through use of self-learning packets. The self-learning packet contained specific terminal objectives and was developed for the first level nursing students focusing on the cognitive learning levels of knowledge, comprehension, and application.

They administered a pretest during the first week of the semester before any formal medication education. The post-test was administered after the conclusion of the posology module. Of the 77 nursing students included in the study, the results of the pretest included a mean score of 52% with a range of 33% to 81% as compared to the results of a post-test mean score of 92.7% with a range

of 76% to 100%. The study revealed that an organized problem-solving method to resolve medication problems can effectively increase the mean score from pretest to post-test. A high-level of acceptance of the posology program was determined through written and verbal evaluative feedback from the faculty and the students. The result of this acceptance led to the development of a second-level posology course focusing on the calculation and administration of intravenous solutions.

Bayne and Bindler (1988) proposed fourteen questions in an exploratory study that examined whether baccalaureate-prepared nurses made fewer medication errors than diploma or associate degree-prepared nurses. A twenty-item, researcher-developed medication calculation examination was administered to a sample of 62 nurses (29 registered nurses and 33 graduate nurses) obtained from two large hospitals in eastern Washington. A questionnaire was used to provide background information about the educational level of the nurses, practice settings, years of experience, and medication administration responsibilities, as well as a self-rating of overall skill in and comfort with medication calculations. The test scores ranged between 20% to 100% with only 35% of the nurses attaining a score of 90% or more, 54% attained 80% or more, and 75% of the

nurses attained a score of 70% or more on the test. Although an analysis of variance showed no significant correlations could be made between the scores obtained on the medication calculation exam, years of experience, level of education, or area of employment, the findings did suggest that many nurses failed to calculate correctly at the 90% level of proficiency.

Bayne and Bindler asserted that there should be great concern that many nurses lack the ability to accurately calculate medication dosages at the 90% level of proficiency. They recommended that hospitals and other health-care institutions consider periodic evaluation of the medication calculation skills of nurses similar to the type of evaluation initiated for cardiopulmonary resuscitation skills.

In a study conducted by Chengler, Conklin, Hirst, Reimer, and Watson (1988), it was identified that nursing students within the province of Alberta had difficulty in performing mathematical calculations. All of the nursing students entering and exiting each nursing program were asked to participate in the study by taking a two-part mathematical test. The mathematical test included computational and problem-solving questions. With mastery defined as a score of 90% or greater, the researchers noted

that of the 210 entering students and 145 exiting students, 60% were unable to achieve mastery in problem-solving and 38.6% failed to achieve mastery in computations. They concluded that the problem was not in the students' computational abilities but in their problem-solving abilities. Their explanation for this conclusion was that problem-solving questions require both cognitive as well as mathematical skills. Based on the results of the study, these investigators recommended the following: a college level math course as a prerequisite for admission into nursing programs; math testing throughout the entire nursing program; remedial programs; and medication calculation mastery before clinical administration of drugs is permitted.

Worrell and Hodson (1989) conducted a random proportional sampling of 223 programs in National League for Nursing (N.L.N.) accredited baccalaureate, diploma, and associate nursing education programs to examine math and dosage calculation abilities. They used a Posology Data Form (a 25-item questionnaire that examined admission requirements, student deficiencies, type of skill tested, calculation methods taught, use of calculators, types of remediation and consequences of failure) to gather data for the study. Results revealed that 41.3% of the programs

surveyed found 11-30% of their nursing students were deficient in basic mathematical skills. A Chi-square test revealed no significant relationship between educational levels and reported deficiency percentage ranges, $\chi^2(2, n=206) = .75, p < .05$.

The study conducted by Worrell and Hodson (1989) also inquired as to how students were instructed in methods of setting up a medication calculation problem. The results revealed that out of 72 baccalaureate nursing programs, there were 48 variations of setting up the dosage calculation problem presented. The 95 associate degree nursing programs involved in the study had 28 variations and the 54 diploma nursing programs had 32 variations. The results identified that the methods used differed in the labeling of the problem and the use of mathematical formulas. The results focused around the multiple variations used to teach students to set up problems. The findings indicated that students may face many inconsistencies when being tutored by multiple nursing faculty members. The most noted inconsistencies identified were the labeling of problems (whether or not the problem was utilizing grains or grams) and the use of different mathematical methodologies. Several recommendations resulted from this study including requiring faculty

consistency in labeling and use of mathematical formulas.

Although much of the research has been focused on the mathematical or computational skills of nursing students, Blais and Bath (1992) conducted a study to analyze the dosage calculation errors of nursing students from conceptual, mathematical, and measurement perspectives. They obtained a convenience sample of 66 nursing students enrolled in an upper-division baccalaureate nursing program at a large public university.

This study focused on determining how many students lacked the skills to accurately calculate drug dosages on a 20-item medication dosage calculation examination and what type of error occurred most often including the frequency. The results revealed that 89% of the students did not perform at a 90% level. Conceptual errors (set-up of the problem) were the most frequent type of mistake in 56% of those problems missed. Errors involving mathematical deficiencies occurred in 19% of the problems and measurement errors (converting between different measurement systems) occurred in 13% of the problems. Bath and Blais concluded that, although students do have difficulty with mathematical and measurement deficiencies, the majority of the deficiencies involve conceptual difficulties. They recommended that schools of nursing

focus not only on assisting the students with problem-solving strategies to conceptualize the dosage calculation problem, but also to be consistent throughout the curriculum with the type of formula the students are instructed to use.

Another study by Bath and Blais (1993) measured the learning styles of 66 nursing students that were enrolled in the first-year courses in an upper-division nursing program at a large public university. Prior to their involvement in the study, all of the students had completed a course involving the calculation of drug dosage and medication administration skills. This study focused on identifying the type of learning style nursing students used to solve the medication calculation problems on a 20-item drug dosage examination. The results indicated that 83% of the nursing students used a learning style identified as the sequential, step-by-step, mathematical problem-solving method involving paper and pencil processing to solve mathematical problems. The results further indicated that only 3% of the nursing students used a learning style identified as the global, all-at-once, mathematical problem-solving method that involves mental processing to solve mathematical problems.

Bath and Blais recommended that nursing faculty members should assess the learning style of their students and develop instructional strategies to meet individual needs. Although the 3% who did use global, all-at-once mathematical problem solving strategies did obtain passing scores of 90% or greater, the study determined that a large percentage of the nursing students used sequential, step-by-step, mathematical problem-solving strategies. They further recommended that reinforcing strategies for these students would include the use of a one consistent formula throughout the curriculum for solving dosage calculation problems because using more than one formula would only augment the problem with confusion.

Segatore, Edge and Miller (1993) conducted a study to identify the incidence and nature of errors in posology made by 44 sophomore nursing students in a baccalaureate nursing program. After administration of a 40-item medication computation quiz, it was determined that only 54% of the students were able to met the pre-established passing standard of 85%. Errors were analyzed according to the type of error including conceptual errors (identified as those involving form or set-up) and arithmetic errors (identified as incorrect addition, subtraction, multiplication, division, use of decimals and fractions).

The results of this study identified that 90.9% of the errors involved conceptual problems with 68.3% set-up errors (failure to provide, or inability to set up the correct formula) and 31.6% form errors (failure to provide the correct form of medication). Arithmetic errors involved only 9.9% of the errors, a phenomenon attributed to the fact that the students were allowed to use calculators. The researchers advised against assuming that nursing students have mastered mathematical skills and recommended that attention be paid to the rationale behind formulas, review of ratio and proportion, and demonstration of multi-step problem solving to enhance the success of problem solving.

As indicated, the nursing literature contained studies that explained the reasons for the medication calculation deficiencies of nurses and nursing students. The chemistry literature focused on studies analyzing the use of different formulas for solving mathematical equations. Although there is a paucity of information within the chemistry literature analyzing different formulas, the chemistry literature has researched dimensional analysis as a problem-solving method for reducing mathematical deficiencies.

In a post-test only control group design, Gabel and Sherwood (1983) conducted a study of 609 randomly selected high school chemistry students in central and south central Indiana to determine whether certain types of instructional strategies were superior to others when teaching problem solving in chemistry courses. The strategies included proportionality, analogies, diagrams, and factor-label method (also known as dimensional analysis). The factor-label method (dimensional analysis) was demonstrated to be the most desirable method for teaching the mole concept. The mole concept can be correlated with the type of medication calculation problems that nursing students or nurses face daily because both concepts require conversions to be made in order to solve the problem.

Bunce and Heikkinen (1986) investigated the effects of teaching an explicit problem-solving approach on the mathematical chemistry achievement of preparatory college students. Introductory chemistry students ($N=200$) were randomly assigned to a control group (receiving instruction with the explicit problem solving approach) and an experimental group (receiving instruction with the problem-solving strategy of dimensional analysis). The results of the study did not demonstrate a statistically significant difference ($F=2.05$, $p=0.092$) with the problem

solving approaches, although the trend was toward improved performance with the students taught dimensional analysis. The study did not elaborate on dimensional analysis as a problem-solving method.

Hauben and Lehman (1988) conducted a study using a post-test only control group design that examined a computer assisted instruction (CAI) module on problem solving with dimensional analysis. The study involved 57 chemistry students that were randomly assigned to a treatment group (28 used the CAI module on dimensional analysis) and a control group (29 used a paper and pencil version). The content for the experimental group (CAI) and the control group (paper/pencil modules) was the same. Both groups were previously exposed to the problem-solving method of dimensional analysis and were familiar with measurements required for conversions.

The means and standard deviations of the post-test scores were analyzed and proved to be significant at the 0.05 alpha level. The experimental group (CAI) was significantly superior ($p \leq .05$) to the control group (paper/pencil) on both volume and word problems but not mass and length. The students in both group also were asked to rate their attitude regarding dimensional analysis as a problem-solving method and both groups were very

positive in their ratings of dimensional analysis, with the experimental group (CAI) significantly more positive ($p < .001$) about the use of dimensional analysis than the control group.

Summary

A number of studies from the nursing literature have identified that medication errors involving inadequate medication calculation abilities of nurses and nursing students remain an ongoing problem. The investigators focused on several reasons for the medication calculation deficiencies of nurses and nursing students. Several studies identified the lack of mathematical skills as the reason for medication errors and introduced remediation with self-learning packets (Bayne and Bindler, 1988; Dexter and Applegate, 1980; Ptaszynski and Silver, 1981). Other studies identified that the problem of medication errors was not only mathematical but conceptual as well and recommended further study (Blais and Bath, 1992; Chenger et al., 1988). One study identified that incorrect labeling of the problem and inconsistencies with teaching different formulas contributed significantly to medication errors (Worrell and Hodson, 1989). Other studies identified that the problem of medication errors involved the inability of the student to conceptualize and set up the problem

correctly (Blais and Bath, 1992; Segatore, Edge, and Miller, 1993). Finally, it was concluded that the learning style of each student needs to be analyzed because the majority of nursing students utilized a step-by-step process that required conceptualization of the problem (Bath and Blais, 1993).

The chemistry literature offered a problem-solving method that can be applied to the teaching of medication dosage calculation--dimensional analysis (Bunce and Heikkinen, 1986; Gabel and Sherwood, 1983). Dimensional analysis is based on cognitive theory that allows conceptualization of the medication calculation problem utilizing a problem-solving method that follows a step-by-step process. Dimensional analysis was shown to be effective with mole conversions which are conceptually similar to the types of medication calculation problems that nurses and nursing students encounter in clinical nursing practice.

CHAPTER THREE METHODOLOGY

The purpose of this study was to examine if the use of the problem-solving method of dimensional analysis would improve the medication dosage calculation abilities of nursing students. This chapter focuses on the research methodology of the study and includes the following sections: research design, sample and sampling plan, data collection instruments, data collection procedures, and protection of human subjects. A brief summary concludes the chapter.

Research Design

The design for this study was a quasi-experimental research design. Although randomization was not possible, a control group was utilized and there was active manipulation of the independent variable (dimensional analysis). As suggested by Campbell and Stanley (1963), to strengthen the study and to compensate for the absence of randomization, a demographic data collection instrument (Appendix 1) and a pretest (Appendix 2) were used to determine if the groups were homogeneous in nature. The quasi-experimental research design was selected because, despite the inability to randomize, it allowed for stronger inferences between the cause and effect

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relationship between variables and assisted in examining more specifically the effects of dimensional analysis and medication calculation abilities of nursing students.

Sample and Sampling Plan

A convenience sample of second level or second year nursing students was obtained. The sample size for the study included 59 nursing students enrolled in nursing programs located in the central Iowa area. The experimental group included 30 nursing students enrolled in a three year diploma nursing education program. The control group included 29 nursing students enrolled in a two year associate nursing education program from a community college (the control group had originally consisted of 31 nursing students but two students dropped out of the nursing program before the study was completed).

After approval to conduct the study was obtained, all of the nursing students enrolled in the second level or second year in the fall semester of a maternal/child nursing course in the diploma nursing program and in the spring semester of a maternal/child nursing course in the associate degree nursing program were asked to participate in the study. All 30 of the nursing students enrolled in the diploma nursing program agreed to participate in

the study as the experimental group receiving medication calculation instruction through use of the problem-solving method of dimensional analysis. All 31 of the nursing students in the associate degree nursing program agreed to participate in the study as the control group receiving medication calculation instruction through use of the problem-solving method of ratio-proportion. Two students dropped from the associate degree nursing program before completion of the research study resulting in a total of 29 nursing students in the control group.

Data Collection Instruments

Two data collection instruments were used for the study. To assist with measuring demographic factors that describe the sample, a demographic data collection instrument (Appendix 1) was administered to all participants to obtain the following information: age, sex, how recently the student had completed a course in introductory chemistry in a community college or university, and how many years of high school mathematics each student had completed. Determining whether or not the student had completed a course in introductory chemistry was considered an important factor because the student may have already been introduced to the problem-solving method of dimensional analysis before

participation in this research study. The information of how many years of high school mathematics were completed also was considered important because students may be functioning at a different level of mathematical proficiency than other students in the research study.

A researcher-developed pretest/post-test (Appendix 2) consisting of 20 medication calculation problems similar to the problems that a registered nurse would encounter with medication administration in clinical nursing practice was given to all subjects in the experimental and control groups. The pretest/post-test consists of 20 open-ended mathematical calculation problems. Six of the problems involve oral medications; two problems involve intramuscular drugs; and twelve problems relate to intravenous medication calculations.

The problems involve calculating with or without a conversion to determine how many tablets or milliliters should be administered. An example of one of these problems is as follows:

Order: Ascorbic Acid 0.5 gm

The bottle is labeled: Ascorbic Acid 500 mg/tablet

How many tablets will you give?

The pretest/post-test also includes problems involving the calculation of the flow rate for intravenous medication administration. An example of this question is:

Order: 1000 ml D5W to infuse in 12 hours

Drop Factor: 15 gtt/ml

Calculate the flow rate in gtts/min

Although oral and intravenous administration of medication are the most frequent problems that would be encountered with medication administration, another type of problem included in the pretest/post-test is the calculation of the dosage of medication to be delivered through the use of intravenous administration. An example of this type of question is:

Dopamine 4 mcg/kg/min

The patient weight: 120 lb

Supply: 250 cc D5W with 400 mg of Dopamine

Calculate ml/hr to set the IV pump.

The nursing students were permitted to use calculators but were asked to show their computation for each problem to allow for evaluation of their problem-solving skills. To assist the nursing students, a conversion table was provided that included the conversions between systems and the definitions of abbreviations used within the

problems.

Content validity of the instrument was established through a review of an existing test developed by Bindler and Bayne (1984). Problems for the pretest/post-test were patterned after the problems utilized by Bindler and Bayne including the number and types of problems. Content validity for this pretest/post-test also was established through examination by four nursing faculty members. Suggestions made by the faculty members to increase content validity included eliminating all unnecessary words within each problem and establishing a consistent order to introduce each problem (the doctor's order, the labeling information, and the dose needed). It also was suggested that the conversion table containing the conversions necessary to complete the problems and a list of abbreviations with definitions be placed on a separate sheet that could be removed from the pretest/post-test to allow for quick reference while completing the problems.

Reliability of the testing instrument was determined through use of the odd-even split half test of reliability. The reliability was 0.714 with 1.0 demonstrating a perfect positive relationship.

Data Collection Procedures

Subjects in the study were informed about the study and their participation in the study through use of the written cover letter (Appendix 4) and a student informed consent form (Appendix 5). The researcher presented information about the study to the experimental group by reading the cover letter and student informed consent form to all 30 nursing students. The researcher had previously planned to present the same information to the control group but due to adverse weather conditions and time schedules, the control group received the information from their community college nursing educator who was instructed by the researcher to read the cover letter and the student informed consent form to all 31 nursing students in the control group. Administration uniformity was achieved by administering the demographic tool (Appendix 1) and the pretest (Appendix 2) to the nursing students in both groups within the first month after enrolling in the nursing course but before any formal instruction on medication administration. The post-test (Appendix 2) was administered to the nursing students in both groups within the last month before completion of the semester.

The nursing students in the experimental group received medication calculation instruction through a two-hour didactic presentation introducing dimensional analysis as a problem-solving method by the researcher. Dimensional analysis was demonstrated and explained as a problem-solving method to the experimental group beginning with simple problems and advancing to complex problems encountered in medication administration in the clinical practice. The concept for each problem was introduced and examples were demonstrated on the blackboard until the concept was understood before advancing to a more difficult problem. The oral presentation was strengthened through the use of a workbook that allowed the student a visual aid as well as a source for additional problem-solving practice (Appendix 6). Throughout the semester, reinforcement and periodic evaluation was maintained with the experimental group through inclusion of three medication calculation problems on each of four examinations, scores on the examinations were not included as part of the student's final grade.

The nursing students in the control group received medication calculation instruction from their community college nursing educator utilizing the ratio-proportion

or desired dose/dose on hand problem-solving methods. To maintain consistency, the nursing students in the control group also received the researcher-developed practice workbook as well as reinforcement and periodic evaluation throughout the semester through the inclusion of three medication calculation problems on each of four examinations, scores on the examinations were not included as part of their grades.

Both groups were required to show their computation for each problem on all examinations to receive credit for correct answers. Both groups received a researcher-developed workbook with medication calculation problems (used with permission from a 1992 published textbook by S. Garner Moore) for practice during the semester. Both groups were offered tutoring if requested.

Protection of Human Subjects

Permission to conduct this study was first obtained from the Drake University Human Subjects Research Review Committee (Appendix 3). Following this approval, permission then was obtained from each of the two schools of nursing that participated in the study (Appendix 3).

The rights of the subjects, including the right to freedom from harm, the right to informed consent and the

right to privacy, were maintained throughout the study. A cover letter (Appendix 4) and student consent form (Appendix 5) were given to each participant. The cover letter included the purpose of the study, the procedures that would be followed, the benefits of participation in the study, the risks of participation in the study, and how the results of the study could be obtained. The participants also were informed that their participation in the study would not affect their student status or grade. The participants in the study were asked to utilize the last four digits of their social security number to allow for matching of the data obtained from the study and to ensure confidentiality. Through use of their four-digit code, all names were kept confidential and reported in aggregate. Student consent forms and data related to the study were kept in a locked file and destroyed at the completion of the study.

Summary

To investigate the effectiveness of dimensional analysis as a problem-solving method, a quasi-experimental research study was designed. The study included 59 nursing students located in the same geographic area (30 nursing students in the experimental group from a diploma nursing

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program and 29 nursing students in the control group from an associate degree nursing program). Two data collection instruments were used for the study. To assist with measuring demographic factors that describe the sample, a demographic data collection instrument (Appendix 1) was administered to all participants. A researcher-developed pretest/post-test (Appendix 2) consisting of 20 medication calculation problems similar to the problems that a registered nurse would encounter with medication administration in clinical nursing practice also was administered to all subjects participating in the research study. Chapter four analyzes the data obtained from the study.

CHAPTER FOUR ANALYSIS OF DATA

The purpose of this study was to examine if the use of dimensional analysis would improve the medication dosage calculation abilities of nursing students. This chapter is divided into four sections. The first section describes the demographic characteristics of the sample. The second section analyzes data related to the research hypotheses. The third section describes additional findings of the study. The final section summarizes the chapter.

Description of the Sample

The experimental group consisted of 30 nursing students enrolled in the second year of a three year diploma nursing program located in central Iowa. As indicated in Table 1, of the 30 nursing students, two (6.67%) were between the ages of 18 and 22, seven (23.33%) were between the ages of 23 and 27, twelve (40%) were between the ages of 28 and 35, and nine (30%) were 36 years of age or older. The experimental group included four (13.33%) male nursing students and 26 (86.67%) female nursing students. One nursing student had completed an introductory chemistry course in a community college or university within the last two years, six (20%) had completed a course within the last three to five years, four (13.33%) had completed

a course within the last six to ten years, five (16.67%) had completed a chemistry course more than ten years ago, and fourteen (46.67%) nursing students had never enrolled in an introductory chemistry course as part of post-secondary education. Seven (23.33%) nursing students had completed only one year of high school mathematics, two (6.67%) students had completed two years, nine (30%) students had completed three years, and twelve (40%) students had completed four years of high school mathematics plus post-secondary education.

The control group consisted of 29 nursing students enrolled in the second year of a two year associate nursing program from a community college located in central Iowa. Of the 29 nursing students, six (20.69%) were between the ages of 18 and 22, eight (27.59%) were between the ages of 23 and 27, ten (34.48%) were between the ages of 28 and 35, and five (17.24%) were 36 years of age or older. The control group included three (10.34%) male nursing students and 26 (89.66%) female nursing students. Eleven (37.93%) of the nursing students had completed an introductory chemistry course in a community college or university within the last two years, eight (27.59%) had completed a course within the last three to five years,

three (10.34%) had completed a course within the last six to ten years, and seven (24.14%) nursing students had never enrolled in an introductory chemistry course as part of post-secondary education. Two (6.90%) nursing students had completed only one year of high school mathematics, four (13.79%) students had completed two years, five (17.24%) students had completed three years, and eighteen (62.07%) students had completed four years of high school mathematics plus post-secondary education.

Table 1

Demographic Characteristics of Experimental and Control Groups

Characteristics	Exp. Group		Con. Group		TOTAL	
	N	%	N	%	N	%
AGE						
18-22	2	6.67	6	20.69	8	13.56
23-27	7	23.33	8	27.59	15	25.42
28-35	12	40.00	10	34.48	22	37.29
36+	9	30.00	5	17.24	14	23.73
TOTAL	30	100.00	29	100.00	59	100.00
SEX						
Male	4	13.33	3	10.34	7	11.86
Female	26	86.67	26	89.66	52	88.14
TOTAL	30	100.00	29	100.00	59	100.00
CHEMISTRY						
Last 2 Years	1	3.33	11	37.93	12	20.34
Last 3-5 Years	6	20.00	8	27.59	14	23.73
Last 6-10 Years	4	13.33	3	10.34	7	11.86
Over 10 Years	5	16.67	0	00.00	5	8.48
Never	14	46.67	7	24.14	21	35.59
TOTAL	30	100.00	29	100.00	59	100.00
HIGH SCHOOL MATHEMATICS						
1 Year	7	23.33	2	6.90	9	15.25
2 Years	2	6.67	4	13.79	6	10.17
3 Years	9	30.00	5	17.24	14	23.73
4 Years +	12	40.00	18	62.07	30	50.85
TOTAL	30	100.00	29	100.00	59	100.00

Research Hypothesis 1

The first research hypothesis for this study was:
Nursing students in the experimental group who are taught dimensional analysis will demonstrate significantly greater improvement in the medication calculation pretest/post-test scores than nursing students in the control group.

To test this hypothesis, scores for the experimental and control groups were obtained using a 20-item medication calculation pretest/post-test consisting of problems similar to the problems that a registered nurse would encounter with medication administration in clinical nursing practice. As discussed previously, possible scores on the pretest/post-test range from 0 to 20. The pretest scores for the experimental group ranged from 0 to 20, with a mean score of 5.167 and a standard deviation of 4.504. The post-test scores for the experimental group ranged from 3 to 20, with a mean score of 14.30 and a standard deviation of 4.721.

A dependent t-test was applied to determine whether or not there was a significant level of improvement in the pretest/post-test scores of the experimental group. An alpha level of .05 was set. As illustrated in Table 2, a statistically significant level of improvement occurred

between the pretest and post-test scores in the experimental group ($p=.00001$).

Table 2

Dependent T-Test Analysis of Pretest/Post-test Differences in the Experimental Group

N	Mean Difference	Standard Deviation	t	df	p
30	9.133	4.761	10.51	29	.00001

The pretest scores for the control group ranged from 4 to 20, with a mean score of 11.138 and a standard deviation of 3.861. The post-test scores for the control group ranged from 10 to 20, with a mean score of 15.069 and a standard deviation of 2.777.

A dependent t-test was applied to determine whether or not there was a significant level of improvement in the pretest/post-test scores of the control group. An alpha level of .05 was set. As illustrated in Table 3, a significant level of improvement occurred between the pretest and post-test scores in the control group ($p=.00001$).

Table 3

Dependent T-Test Analysis of Pretest/Post-test Differences in the Control Group

N	Mean Difference	Standard Deviation	t	df	p
29	4.138	2.735	8.15	28	.00001

Although a significant level of improvement ($p=.00001$) was demonstrated between the pretest and post-test scores of the experimental group, a similar significant level of improvement ($p=.00001$) was demonstrated between the pretest scores and the post-test scores of the control group. To determine if the increased level of improvement between the pretest scores and the post-test scores for the experimental group was significantly greater, an independent t-test of the mean differences between the pretest/post-test scores of the experimental and control groups was applied. As illustrated in Table 4, a statistically significant difference in the level of improvement was found between the two groups ($p=.00001$).

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Table 4

Independent T-Test Analysis of Mean Differences in the
Pretest/Post-test Scores of the Experimental and the Control
Groups

	N	Mean Difference	Standard Deviation	df	t	p
Exp. Group	30	9.13	4.76	57	4.96	.00001
Con. Group	29	4.14	2.74			

Thus, the research hypothesis that nursing students in the experimental group who were taught dimensional analysis would demonstrate significantly greater improvement in the medication calculation pretest/post-test scores than nursing students in the control group was supported. The experimental group who used dimensional analysis demonstrated a statistically significant greater level of improvement in the pretest/post-test scores than the control group.

Research Hypothesis 2

The second hypothesis for this research study was: Nursing students in the experimental group who are taught dimensional analysis will have higher scores on the medication calculation post-test than the nursing students

in the control group.

To test this hypothesis, scores for the experimental and control groups were obtained from the 20-item post-test. As discussed previously, possible scores on the post-test range from 0 to 20. The post-test scores for the experimental group ranged from 3 to 20, with a mean score of 14.30 and a standard deviation of 4.721. The post-test scores for the control group ranged from 10 to 20, with a mean score of 15.069 and a standard deviation of 2.777. As demonstrated in Table 5, when an independent t-test was applied ($p=.05$), the difference in post-test scores between the experimental and control groups was not significant ($p=0.78$).

Table 5

Independent T-Test Analysis of Differences in the Post-test Scores of the Experimental and the Control Groups

	N	Mean Difference	Standard Deviation	df	t	p
Exp. Group	30	14.30	4.72	57	-.77	.78
Con. Group	29	15.07	2.78			

Thus, the research hypothesis that nursing students in the experimental group who are taught dimensional analysis would have higher scores on the medication calculation post-test than the nursing students in the control group was not supported. There was no significant difference between the post-test scores of the experimental and control groups.

Additional Findings

One additional finding that was observed was that accuracy of response seemed to be dependent on the number of steps required to complete the problem. As illustrated in Table 6, the item analysis of the pretest/post-test scores revealed that accuracy of student responses appeared to be dependent on the number of steps required to complete the problem. Another factor related to accuracy of student responses seemed to involve whether or not a problem required a conversion or conversions to successfully complete the problem.

To analyze this finding, an item analysis of each of the 20 pretest/post-test questions first was completed. Analysis of the post-test scores for the experimental group and the control group revealed that 28 (93.33%) experimental nursing students and 27 (93.10%) control nursing students

answered problem #1 (two steps with no conversions) correctly. Although two experimental nursing students did set the problem up correctly, they did not receive a correct answer because of mathematical errors with division. One control nursing student had a mathematical error and one student labeled the problem incorrectly.

Problem #2 (three steps with one conversion) was answered correctly by 29 (96.67%) experimental nursing students and 29 (100%) control nursing students. One experimental nursing student set the problem up correctly but used a wrong conversion.

Problem #3 (three steps with one conversion) was answered correctly by 23 (76.67%) experimental nursing students and 21 (72.41%) control nursing students. Seven experimental nursing students set up the problem correctly but had difficulty because of the fraction and did not multiply correctly. Eight control nursing students had mathematical errors.

Problem #4 (three steps with no conversion) was answered correctly by 22 (73.33%) experimental nursing students and 24 (82.76%) control nursing students. Five experimental nursing students set the problem up incorrectly; one had a problem with the weight conversion;

one read the problem incorrectly; and one did not try to complete the problem even though it was set up correctly. Five control nursing students had mathematical errors.

Problem #5 (three steps with one conversion) was answered correctly by 20 (66.67%) experimental nursing students and 29 (100%) control nursing students. Two experimental nursing students read the problem incorrectly; one student had a mathematical error related to division; one student had a conversion error; one student set up the problem but did not complete it; and five students did not attempt the problem.

Problem #6 (two steps with no conversion) was answered correctly by all 30 (100%) experimental nursing students and 28 (96.55%) control nursing students. One control nursing student had a mathematical error.

Problem #7 (three steps with one conversion) was answered correctly by 18 (60%) experimental nursing students and 21 (72.41%) control nursing students. Six experimental nursing students set the problem up incorrectly; two had a problem with the weight conversion; one student read the problem incorrectly; one student had a mathematical error related to division, one student had a mathematical error related to multiplication; and one student did not

attempt to answer the problem. Two control nursing students did not show their work and six students had mathematical errors.

Problem #8 (three steps with one conversion) was answered correctly by 25 (83.33%) experimental nursing students and 29 (100%) control nursing students. Two experimental nursing students read the problem incorrectly; one student made a mathematical error because of internal dividing within the problem; and two students did not attempt to answer the problem.

Problem #9 (four steps with two conversions) was answered correctly by 19 (63.33%) experimental nursing students and 20 (68.97%) control nursing students. One experimental nursing student made a mathematical error because of internal dividing within the problem; four students set the problem up incorrectly; four students did not have the drop factor portion of the problem set up correctly; one student set the problem up correctly but did not attempt to complete the problem; and one student did not attempt to answer the problem. Four control nursing students did not attempt to solve the problem; three students did not show their work; and two students had mathematical errors.

Problem #10 (two steps with no conversions) was answered correctly by 22 (73.33%) experimental nursing students and 27 (93.10%) control nursing students. Three experimental students read the problem incorrectly and five students did not attempt to answer the problem. One control nursing student did the work and one student had a mathematical error.

Problem #11 (six steps with three conversions) was answered correctly by 18 (60%) experimental nursing students and 18 (62.07%) control nursing students. Two experimental nursing students set the problem up incorrectly; one student read the problem incorrectly; one student used a conversion that was not necessary for the problem; four students used an incorrect weight conversion (one pound equals 2.2 kilograms); and four students did not attempt to answer the problem. Nine control nursing students had mathematical errors and two students did not attempt to solve the problem.

Problem #12 (three steps with one conversion) was answered correctly by 11 (18.33%) experimental nursing students and 7 (24.14%) control nursing students. The remainder of the experimental students (19) attempted to answer the problem but did not know how to set it up

correctly. Four control nursing students did not show their work; two students did not attempt to solve the problem; one student did not complete the problem; and fifteen students had mathematical errors.

Problem #13 (four steps with one conversion) was answered correctly by 17 (56.67%) experimental nursing students and 17 (58.62%) control nursing students. Four experimental nursing students did not have the drop factor portion of the problem set up correctly; four students did not set the problem up correctly; one student had a mathematical error involving multiplication; one student neglected to use a conversion (one hour equals 60 minutes); and three students did not attempt to answer the problem. Four control nursing students did not attempt to solve the problem and eight students had mathematical errors.

Problem #14 (two steps with no conversions) was answered correctly by 25 (83.33%) experimental nursing students and 25 (86.21%) control nursing students. One experimental nursing student had a mathematical error involving multiplication; one student had a mathematical error involving division; one student used a conversion that was not needed (one hour equals 60 minutes); and two students did not attempt to answer the problem. Three

control nursing students had mathematical errors and one student did not show the work.

Problem #15 (six steps with three conversions) was answered correctly by 17 (56.67%) experimental nursing students and 22 (75.86%) control nursing student. One experimental nursing student had a mathematical error involving multiplication; four students set the problem up incorrectly; three students mislabeled the conversion (one pound equals 2.2 kilograms); one student did not use the conversion (one hour equals 60 minutes); and three students did not attempt to answer the problem. Three control nursing students had mathematical errors; one student did not show the work; and three students did not attempt to solve the problem.

Problem #16 (three steps with one conversion) was answered correctly by 20 (66.67%) experimental nursing students and 24 (82.76%) control nursing students. One experimental nursing student incorrectly read the problem; three students did not set up the drop factor portion of the problem correctly; one student had a mathematical error involving multiplication; one student had a conversion error; and four students did not attempt to answer the problem. Five control nursing students had mathematical

errors.

Problem #17 (three steps with no conversions) was answered correctly by 16 (53.33%) experimental nursing students and 14 (48.28%) control nursing students. Four experimental nursing students attempted to answer the problem; three students set the problem up incorrectly; and seven students did not attempt to answer the problem. Eleven control nursing students had mathematical errors; three students did not attempt to solve the problem; and one student did not show the work.

Problem #18 (three steps with one conversion) was answered correctly by 26 (86.67%) experimental nursing students and 17 (58.62%) control nursing students. One experimental nursing student set the problem up wrong; one student did not show the work; and two students did not attempt to answer the problem. Seventeen control nursing students failed to convert milliliters to teaspoons.

Problem #19 (three steps with one conversion) was answered correctly by 21 (70%) experimental nursing students and 21 (72.41%) control nursing students. Two experimental nursing students set the problem up correctly but did not complete the problem; two students had conversion errors; one student had a mathematical error related to internal

dividing; one student read the problem incorrectly; one student set the problem up wrong; and two students did not attempt to answer the problem. Three control nursing students did not attempt to solve the problem; one student did not show the work; and five students had mathematical errors.

Problem #20 (two steps with no conversions) was answered correctly by 21 (70%) experimental nursing students and 15 (51.72%) control nursing students. One experimental nursing student set the problem up incorrectly; one student had a mathematical error involving division; two students read the problem incorrectly; one student used a conversion that was not needed (one hour equals 60 minutes); and four students did not attempt to answer the problem. Three control nursing students did not attempt to solve the problem and eleven students had mathematical errors.

Following the item analysis, a correlation coefficient was used to correlate the number of conversions and steps in each problem with the number of correct responses on the post-test for the experimental group, control group, and both groups combined. As illustrated in Table 6, the data revealed that when the number of steps was correlated with the number of correct responses on the post-test of

the experimental group, a moderate inverse relationship was found ($r=-0.476$), indicating that as the number of steps required to solve the problem increased, the accuracy of student response decreased. A slight inverse relationship was found in the control group ($r=-0.238$) and both groups combined ($r=-0.371$). The data also revealed that when the number of conversions was correlated with the number of correct responses on the post-test of the experimental group, a slight inverse relationship was found ($r=-0.340$). The number of conversions correlated with the number correct on the post-test of the control group ($r=-0.151$) and both groups combined ($r=-0.253$) was found to be slightly inversely related. The inverse correlation supports the notion that as the number of steps and conversions increased, the number of students who obtained a correct answer decreased for the experimental group, the control group, and both groups combined.

Table 6

Correlations of Number of Steps and Conversions with the Accuracy of Post-test Scores of the Experimental and Control Groups

	# of Conversions	# of Steps	Exp. Group	Con. Group	Total
Problem 1	0	2	28	27	55
2	1	3	29	29	58
3	1	3	23	21	44
4	0	3	22	24	46
5	1	3	20	29	49
6	0	2	30	28	58
7	1	3	18	21	39
8	1	3	25	29	54
9	2	4	19	20	39
10	0	2	22	27	49
11	3	6	18	18	36
12	1	3	11	7	18
13	1	4	17	17	34
14	0	2	25	25	50
15	3	6	17	22	39
16	1	3	20	24	44
17	0	3	16	14	30
18	1	3	26	17	43
19	1	3	21	21	42
20	0	2	21	15	36
			Experimental Group	Control Group	Total
Correlation of			r=-0.476	r=-0.238	r=-0.371
# of Steps			r=-0.340	r=-0.151	r=-0.253
# of Conversions					

Another finding from the study that requires consideration was the apparent difference in the mean test scores between the experimental group and the control group. To analyze this difference, an independent t-test was applied to the pretest scores of the experimental and control groups to determine whether or not there was a significant difference. As illustrated in Table 7, when an independent t-test was applied ($p=.05$), the difference in pretest scores between the experimental and control groups was significant ($p=.00001$).

Table 7

Independent T-Test Analysis of Pretest Scores of the Experimental and the Control Groups

	N	Mean Difference	Standard Deviation	df	t	p
Exp. Group	30	5.17	4.50	57	-5.55	.00001
Con. Group	29	11.13	3.79			

Summary

To determine the effectiveness of dimensional analysis as a problem-solving method to improve the medication calculation abilities of nursing students, two hypotheses were tested with an experimental group of 30 diploma nursing students and a control group of 29 associate degree nursing students. A statistically significant greater improvement was found when comparing the mean differences of the pretest/post-test scores of the experimental group and the control group ($t=4.96$, $p=.00001$). No significant difference, however, was found when comparing the post-test scores of the experimental group with the post-test scores of the control group ($t=-.77$, $p=.78$).

An additional finding revealed an inverse relationship for the experimental group and the control group between the accuracy of student responses and the number of steps required to solve the problems (experimental $r=-0.476$, control $r=-0.238$, and combined $r=-0.371$) and the number of conversions required to solve the problems (experimental $r=-0.340$, control $r=-0.151$, and combined $r=-0.253$). Another finding demonstrated that there was a significant difference between the pretest scores of the experimental group and the control group ($t=-5.55$, $p=.00001$) that was somewhat

expected based on the chemistry and mathematical differences that were revealed on the demongraphic tool.

CHAPTER FIVE SUMMARY, DISCUSSION, AND RECOMMENDATIONS

Summary

The purpose of this study was to examine if the use of the problem-solving method of dimensional analysis would improve the medication dosage calculation abilities of nursing students. To investigate the effectiveness of dimensional analysis, a quasi-experimental research study was designed. The 59 nursing students participating in the study included an experimental group of 30 nursing students from a diploma nursing program located in central Iowa and a control group of 29 nursing students from an associate degree nursing program located in the same geographic area.

Two research hypotheses were proposed for this study. The first research hypothesis was: Nursing students in the experimental group who are taught dimensional analysis will demonstrate significantly greater improvement in the medication calculation pretest/post-test scores than nursing students in the control group. This hypothesis was supported ($t=4.96$, $p=.00001$).

The second research hypothesis was: Nursing students in the experimental group who are taught dimensional analysis will have higher scores on the medication

calculation post-test than the nursing students in the control group. This hypothesis was not supported ($t=-.77$, $p=.78$).

An additional finding obtained from determination of correlations demonstrated that there was a slight to moderate inverse relationship with the number of steps and conversions in each problem when correlated with the number of correct responses on the post-test for the experimental group (steps/ $r=-0.476$, conversions/ $r=-0.340$), control group (steps/ $r=-0.238$, conversions/ $r=-0.151$), and both groups combined (steps/ $r=-0.371$, conversions/ $r=-0.253$). The slight inverse correlation supports the notion that as the number of steps and conversions necessary to complete the problem increased, accuracy of student response decreased.

Another finding demonstrated that there was a significant difference between the pretest scores of the experimental group and the control group ($t=-5.55$, $p=.00001$). This was somewhat expected based on the chemistry and mathematical differences that were revealed on the demographic tool.

Discussion

Findings from research hypothesis one supported that the nursing students in the experimental group who were taught the problem-solving method of dimensional analysis had a significantly greater improvement in the pretest and post-test scores ($p=.00001$) than the nursing students in the control group. This result is consistent with the findings in the chemistry literature (Gabel and Sherwood, 1983; Hauben and Lehman, 1988) that concluded that dimensional analysis is a valuable method for teaching problem-solving concepts that require numerous steps and conversions to solve the problem.

Gabel and Sherwood (1983) identified that dimensional analysis was the most effective method for teaching the mole concept to chemistry students. The mole concept is similar to the type of medication dosage calculation problems that nurses or nursing students might encounter in the clinical practice. Both types of problems can require numerous steps and conversions to be able to obtain an answer.

Hauben and Lehman (1988) recognized dimensional analysis as an effective problem-solving method and focused on determining which type of methodology was most desirable

when teaching dimensional analysis to chemistry students. Despite the methodology utilized by the experimental group (CAI) or the control group (paper and pencil modules), both groups were positive in their ratings of dimensional analysis as an effective problem-solving method.

Findings from research hypothesis two revealed that students in the experimental group did not have significantly higher post-test scores than students in the control group. This result was somewhat anticipated because the control group obtained a mean score of 11.138 on the pretest compared to the mean score of 5.167 obtained by the experimental group. The demographic data demonstrated that the control group had more years of chemistry and mathematics which may have assisted them in obtaining higher scores on the pretest than the experimental group. Although the control group did obtain a higher mean score on the pretest, the lack of mathematical skills for both groups is consistent with the findings within the nursing literature. A number of studies from the nursing literature have identified that medication errors involving inadequate medication dosage calculation abilities of nurses and nursing students remain an ongoing problem (Bayne and Bindler, 1988; Cheng et al., 1988;

Dexter and Applegate, 1980; Perlstein et al., 1979; Ptaszynski and Silver, 1981; Worrell and Hodson, 1989).

Additional findings of the study obtained from determining correlations revealed that when the number of steps and conversions were correlated with the number of correct responses, an inverse relationship occurred. This inverse correlation supports the notion that as the number of steps and conversions increased, the number of students who obtained a correct answer decreased for the experimental group, the control group, and both groups combined. This result also was consistent with information obtained from the nursing literature (Bath and Blais, 1993; Blais and Bath, 1992; Segatore, Edge and Miller, 1993).

Blais and Bath (1992) identified three areas of deficiencies for nurses and nursing students. These areas include mathematical, conceptual, and measurement abilities. They identified that the most frequent type of mistake was conceptual errors (difficulty in setting up the problem). They recommended that schools of nursing focus on assisting the students with problem-solving strategies with a consistent method that allows conceptualization of the problem.

Bath and Blais (1993) focused on learning style as a predictor of medication dosage calculation ability. The results of the study revealed that 83% (N=66) display sequential, step-by-step, paper and pencil mathematical strategies. Only 3% (N=66) displayed global, all-at-once, mental processing. They recommended that nursing faculty members should assess the learning style of their students and develop instructional strategies to meet individual needs. They also recommended that reinforcing strategies for these students would include the use of one consistent method of problem-solving throughout the curriculum for solving medication dosage calculation problems.

Segatore, Edge, and Miller (1993) conducted a study and identified that conceptual errors (form and setup) were the most frequent type of error. They recommended that the demonstration of multi-step problem solving be utilized to enhance the student success of problem-solving.

In this study, dimensional analysis was demonstrated to be an effective problem-solving method that assisted the experimental nursing students in developing mathematical and conceptual skills. Despite the lack of previous chemistry and mathematical experience, dimensional analysis assisted the nursing students in the experimental group

to acquire the skills necessary to conceptualize the problem and significantly improve their scores on the post-test. Although the post-test scores of the experimental group were not significantly higher than the control group, their improvement certainly warrants consideration for further research using dimensional analysis as a problem-solving method.

Limitations

The most significant limitation of the study was the sample. The sample was small, not randomly selected and not necessarily representative of diploma or associate degree nursing students or any nursing student. Thus, the generalizability of the findings from this study is limited.

Another major limitation of the study was the differences in the chemistry and mathematical backgrounds identified on the demographic tool between the experimental group and the control group. This limitation needs to be considered when evaluating the statistical findings of the hypotheses. Although the first research hypothesis was supported, the statistical significance may have been more noteworthy if the experimental group and the control group had been more homogenous in chemistry and mathematical

backgrounds. The second research hypothesis may have been supported if the experimental group and the control group had been more homogenous in nature in their chemistry and mathematical backgrounds. If the groups had been more similar, the statistical findings would have been more focused on the independent variable - dimensional analysis.

Another major limitation of the study was the validity and reliability of the pretest/post-test. Although the problems on the pretest/post-test were patterned after an existing test (Bindler and Bayne, 1984), reviewed by faculty members, and a reliability of 0.714 was determined, it is researcher-developed and the validity and reliability of the tool are not well established.

Another limitation of the study was the timing of the post-test. Some factors that may have contributed to the variations in the pretest/post-test scores for the experimental group as well as the control group were differences due to transient personal factors or situational factors. Transient personal factors would involve such conditions as the mood of the student, state of health, and levels of fatigue and stress. Situational factors influencing the pretest/post-test scores would include such conditions as the timing of the test. The post-test

was administered to the nursing students in the experimental group and control group at a time when the levels of fatigue and stress for the students may have been high. The post-test was administered to both groups of students after completing their semester final examinations which is frequently a period which results in fatigue and stress. Because of the high levels of fatigue and stress, the students may not have placed much importance on the post-test or put much effort into solving the problems. This notion can be supported by the high numbers of unanswered questions. The students also knew that the test scores obtained during this research study would not be included as part of their final semester grade so their motivation to perform at their highest level may have been low.

Another limitation of the study included the differences in test administration. Although the researcher had planned to administer the pretests/post-tests to both the experimental group and the control group, adverse weather conditions and time scheduling made this impossible. Variation in the test results could have been related to the fact that the tests were not administered to both the experimental group and the control group by the researcher.

The students may have failed to perceive the importance or significance of the study.

Recommendations for Future Research

Although randomization was not possible for this study, the researcher recommends that the study be repeated with a larger and more heterogeneous sample that would be more representative of the target population. The medication calculation abilities of associate, diploma and baccalaureate nursing education programs as well as practicing nurses should be studied. This would allow comparisons of the chemistry and mathematical abilities of students from the different levels of nursing education. It also would allow for further refinement of the pretest/post-test through repeated usage with a larger sample that is more representative of the target population.

Another recommendation for future research would be to conduct a longitudinal study that would involve administering the post-test to the experimental group and the control group after a three-year time period had elapsed. This could determine whether or not the use of dimensional analysis remains inherent or is forgotten with disuse.

Another study that might be conducted would be to survey nurse educators and staff development coordinators to identify which methods they use to teach or reinforce the medication dosage calculation abilities of nurses or nursing students. This study would assist in determining what and how nurses or nursing students are being taught as well as determining how much chemistry and mathematical background each person may have.

Significance for Advanced Nursing Practice

The nursing literature identified that mathematical and dosage calculation deficiencies are a problem within the nursing discipline. This study was significant for advanced nursing practice because of the legal as well as the professional responsibility of nurses and nursing students when administering medication. Medication errors by nurses and nursing students related to calculation deficiencies threaten patient safety and are costly in terms of malpractice litigation.

This study examined an alternative method of improving the medication dosage calculation abilities of nursing students by using the problem-solving method of dimensional analysis. Because the problem of medication errors exists within the nursing profession, the nursing profession should

research and evaluate teaching methods that could improve the medication calculation abilities of nurses and nursing students.

Recent literature that has examined the quality of higher education and professional education in the United States (National Institute of Education, 1984) recommends that educators increase the emphasis of the intellectual skills of problem-solving and critical thinking. Also recommended is an increase on the emphasis of the mastery of concepts rather than specific facts. Other literature on curriculum revolution in nursing (Bevis, 1988; Lindeman, 1989; Tanner, 1988) is recommending a rethinking of learning. They contend that learning can not be characterized as merely a change in behavior or the acquisition of facts but in seeing and understanding the significance of the whole. Dimensional analysis supports conceptual mastery and higher level thinking skills advocated in the higher education and nursing education literature.

Dimensional analysis is a problem-solving method that could be considered and adopted by many different areas in nursing. As a problem-solving method, dimensional analysis allows conceptualization of a problem. Through

critical thinking, the concept of dimensional analysis supports visualization of all parts of a problem.

As a method of reducing medication errors and improving medication dosage calculation abilities, dimensional analysis has many possibilities. Staff development departments within hospitals might consider dimensional analysis as a means of remediation for nurses who are experiencing difficulty with medication dosage calculations. Nurses experiencing difficulty with medication dosage calculation could be identified through a yearly mathematical evaluation similar to cardiopulmonary resuscitation (CPR) renewal. Schools of nursing might consider dimensional analysis as a consistent problem-solving method to ensure continuity throughout the curriculum thereby reducing the confusion encountered by students when multiple methodologies are used. Regardless of whether it is used in practice or education, dimensional analysis remains an avenue to be considered when the goal is improvement of medication dosage calculation abilities, reduction of medication errors, and patient safety.

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APPENDIX 1
Demographic Tool

Demographic Tool

Date: _____

Identification Number: _____

To assist with this study, please provide the following information by circling the answer that best describes you:

Q-1. Identify your age category:

1. 18 - 22
2. 23 - 27
3. 28 - 35
4. 36 and above

Q-2. Identify your sex:

1. Male
2. Female

Q-3. How recently did you complete an introductory chemistry course in a community college or university?

1. within the last two years
2. within the last three to five years
3. within the last six to ten years
4. more than ten years ago
5. never enrolled in a chemistry course as part of my post-secondary education

Q-4. How many years of high school mathematics did you complete?

1. one
2. two
3. three
4. four plus post-secondary education

APPENDIX 2
Medication Calculation Test

Medication Calculation Test

Date: _____

Identification Number: _____

This medication calculation test is a tool to assess the mathematical abilities of nursing students. Calculate the following problems and **show your computation for each problem**. Calculators may be used. A conversion table on the last page of this test is provided to assist with computation.

1. Order: Digoxin 0.125 mg
The bottle is labeled: Digoxin 0.25 mg/tablet
How many tablets will you give?

Answer: _____

2. Order: Ascorbic Acid 0.5 gm
The bottle is labeled: Ascorbic Acid 500 mg/tablet
How many tablets will you give?

Answer: _____

3. Order: Atropine gr 1/150
The bottle is labeled: Atropine 0.4 mg/ml
How many ml's will you give?

Answer: _____

4. Order: Vancomycin 2 mg/kg
The patient weighs: 75 kg
The bottle is labeled: Vancomycin 500 mg/10 ml
How many ml's will you give?

Answer: _____

5. Order: ASA gr X
The bottle is labeled: ASA 325 mg/tablet
How many tablets will you give?

Answer: _____

6. Order: Demerol 50 mg IM
The syringe is labeled: Demerol 100 mg/ml
How many ml's will you give?

Answer: _____

7. Order: Ampicillin 2 mg/kg
The patient weighs: 100 lb
The bottle is labeled: Ampicillin 500 mg/5 ml
How many ml's will you give?

Answer: _____

8. Order: 1000 ml D5W to infuse in 12 hours
Drop Factor: 15 gtt/ml
Calculate the flow rate in gtt/min.

Answer: _____

9. Order: 500 ml D5W to infuse at 21 gtt/min
Drop Factor: 15 gtt/ml
Calculate how many hours it will take for the IV to infuse.

Answer: _____

10. Order: Heparin 1500 units/hr
Supply: 250 cc bag of D5W with 25,000 units of Heparin
Calculate ml/hr to set the IV pump.

Answer: _____

11. Order: Dopamine 4 mcg/kg/min
The patient weighs: 120 lb
Supply: 250 cc D5W with 400 mg of Dopamine
Calculate ml/hr to set the IV pump.

Answer: _____

12. Order: Staphcillin 750 mg
The bottle is labeled: Staphicillin 6 gm.
Reconstitute with 8 ml of sterile water to yield
1 gm/ml
How many ml's will you give?

Answer: _____

13. Order: 1000 cc NS to infuse at 50 gtt/min
Drop Factor: 15 gtt/ml
Calculate how many hours it will take for the IV to
infuse.

Answer: _____

14. Order: Regular Insulin 8 units per hour
Supply: 250 cc NS with 100 units of Regular Insulin
Calculate ml/hr to set the IV pump.

Answer: _____

15. Order: Nipride 0.8 mcg/kg/min
The patient weighs: 143 lb
Supply: 500 cc D5W with 50 mg Nipride
Calculate ml/hr to set the IV pump.

Answer: _____

16. Order: 500 cc of 10% Lipids to infuse in 8 hours
Drop Factor: 10 gtt/ml
Calculate the flow rate in gtt/min.

Answer: _____

17. Order: KCL 2 mEq per 100 ml of D5W
The bottle is labeled: 20 mEq/10 ml
Supply: 500 cc D5W
How many ml's of KCL will you add to the IV bag?

Answer: _____

18. Order: Mycostatin oral suspension 500,000 units
swish/swallow
The bottle is labeled: Mycostatin 100,000 units/ml
How many teaspoons will you give?

Answer: _____

19. Order: Aminophylline 44 mg/hr
Supply: 250 cc of D5W with 1 gm of Aminophylline
Calculate ml/hr to set the IV pump.

Answer: _____

20. Order: Dilaudid 140 ml/hr
Supply: 1000 cc D5/NS with 30 mg of Dilaudid
Calculate mg/hr that the patient is receiving.

Answer: _____

APPENDIX 3

Agency Informed Consent

Agency Informed Consent

Name of Investigator: Gloria P. Craig, R.N., B.S.N.

Title of Research Project: The Effects of Dimensional Analysis on the Medication Dosage Calculation Abilities of Nursing Students.

_____ (name of agency) agrees to participate in the present study being conducted under the supervision of Sandra L. Sellers, R.N., Ph.D., a faculty member of Drake University, Division of Nursing, Des Moines, Iowa. The agency has been informed, either orally or in writing or both, about the purpose of the study, the benefits of the study, the procedures to be followed and any discomforts or risks that may be involved. The investigator has offered to answer further questions that the agency may have regarding the procedures of the study. The agency understands that it is free to terminate its participation at any time without penalty or prejudice. The agency is aware that further information about the study can be obtained by calling the researcher's advisor at 515/271-2754.

_____ day month year (signature of administrator of agency)

Agency Informed Consent

Name of Investigator: Gloria P. Craig, R.N., B.S.N.

Title of Research Project: The Effects of Dimensional Analysis on the Medication Dosage Calculation Abilities of Nursing Students.

Dr. Mettler's School of Nursing (name of agency) agrees to participate in the present study being conducted under the supervision of Sandra L. Sellers, R.N., Ph.D., a faculty member of Drake University, Division of Nursing, Des Moines, Iowa. The agency has been informed, either orally or in writing or both, about the purpose of the study, the benefits of the study, the procedures to be followed and any discomforts or risks that may be involved. The investigator has offered to answer further questions that the agency may have regarding the procedures of the study. The agency understands that it is free to terminate its participation at any time without penalty or prejudice. The agency is aware that further information about the study can be obtained by calling the researcher's advisor at 515/271-2754.

11 11 92 Patricia E. Bradley, R.N., M.S.
 day month year (signature of administrator of agency)

Agency Informed Consent

Name of Investigator: Gloria P. Craig, R.N., B.S.N.

Title of Research Project: The Effects of Dimensional Analysis on the Medication Dosage Calculation Abilities of Nursing Students.

Marshalltown Comm College (name of agency) agrees to participate in the present study being conducted under the supervision of Sandra L. Sellers, R.N., Ph.D., a faculty member of Drake University, Division of Nursing, Des Moines, Iowa. The agency has been informed, either orally or in writing or both, about the purpose of the study, the benefits of the study, the procedures to be followed and any discomforts or risks that may be involved. The investigator has offered to answer further questions that the agency may have regarding the procedures of the study. The agency understands that it is free to terminate its participation at any time without penalty or prejudice. The agency is aware that further information about the study can be obtained by calling the researcher's advisor at 515/271-2754.

6 - 1 - 93 Maureen A. Hunt RN MS
day month year (signature of administrator of agency)

APPENDIX 4
Cover Letter

Cover Letter

Dear Student:

As a nurse and a nursing instructor, I am concerned about the mathematical calculation abilities of nursing students. Nursing students are expected to administer medication using the five rights of drug administration that includes the ability to correctly calculate medication problems.

The purpose of this study is to investigate a strategy for improving the mathematical calculation abilities of nursing students. The benefit of being involved in this study is being part of an extensive study focusing on improving medication dosage calculation abilities of nursing students. The study will compare the mathematical calculation abilities of nursing students using ratio proportion and desired dose/dose on hand with nursing students using the chemistry strategy of dimensional analysis. The study is being conducted in connection with my master's degree requirements at Drake University, Division of Nursing, Des Moines, Iowa.

Because you are a nursing student, you have been selected to participate in this study. In no way will your participation or non-participation in this study

affect your grade or student status. Your participation in this study is entirely voluntary, and you are free to stop at any time. The pretest/post-test will take approximately 40 minutes to complete each time you take the test. Your signature on the student informed consent will be your consent to participate in this study. In order to ensure your anonymity and protect confidentiality, your name should not be placed on the demographic tool or on the pretest/post-test, instead, please use the last four digits of your social security number.

If you would like a summary of the findings of this study, a copy can be obtained from the participating college or school of nursing. Further information about this study can be obtained by contacting my advisor, Sandra L. Sellers, R.N., Ph.D., at 515/271-2754. Thank you in advance for your participation in this study.

Sincerely,

Gloria P. Craig, R.N., B.S.N.

APPENDIX 5
Student Informed Consent

Student Informed Consent

I have read and understand the attached cover letter
and agree to participate as described in the study,
The Effects of Dimensional Analysis on the Medication
Dosage Calculation Abilities of Nursing Students.

Student

Date

Researcher

Date

APPENDIX 6

Workbook

NURSING MATH SIMPLIFIED

"Math Magic"

by

Susan Garner Moore, R.N.

St. Petersburg Junior College

adapted by

Gloria P. Craig, R.N., B.S.N.

*Used with permission

NURSING MATH SIMPLIFIED
"Math Magic"

by

Susan Garner Moore, R.N.
St. Petersburg Junior College
adapted by

Gloria P. Craig, R.N., B.S.N.

*Used with permission

Math need not be difficult, you just need a problem-solving method that is easy to understand and implement. Dimensional analysis is a method that is set up like working with fractions - all you need to do is:

- * Multiply numerators, multiply denominators and divide.

$$\frac{\text{numerator}}{\text{denominator}}$$

- * The problem is set up to cancel out unwanted categories, leaving the remaining category needed to answer the problem.
- * Anything you cancel on the top portion of the problem (numerator) must also be canceled on the bottom portion of the problem (denominator).
- * To be able to complete some problems, conversion factors listed below may be needed:

1 gm = 15 gr
1 gr = 60 mg
1000 mg = 1 gm
1 mg = 1000 mcg
1 kg = 2.2 lb
1 tsp = 5 ml
1 Tbl = 15 ml
1 oz = 30 ml
1 dr = 5 ml
1 ml = 15 or 16 m

gm = gram
gr = grain
mg = milligram
mcg = microgram
kg = kilogram
lb = pound
tsp = teaspoon
Tbl = tablespoon
ml = milliliter
dr = dram
m = minim

Let's get started!

The first concept is used with general medication dosage problems and involves administering medication in the form of cc or ml, tablet, or capsule. The concept includes:

First Component - The Doctor's Order

Second Component - Dosage of Medication on Hand

Third Component - Conversion Factor (if needed)

Naturally, anything that the Doctor orders must be the first component of the problem.

Likewise, the second component of the problem needs to be the dosage that is on hand, or more specifically the dosage of medication that is available for you.

Now, if the Doctor orders a specific dosage and you look in your medication supply and find (to your total surprise and bewilderment) a different medication equivalent than the dosage ordered by the Doctor, then you will need the third component of the problem - the conversion factor.

EXAMPLE:

The Doctor orders Terramycin 500 mg. The dosage on hand is 5/6 gr per ml. How many ml's will you give?

The first component of the problem is the Doctor's order, which is 500 mg. Like all fractions, the numerator needs a denominator, and in this case you can use 1 because you have no other specific information in the order.

$$\frac{500 \text{ mg}}{1} \quad (1\text{st component})$$

The second component of the problem is the dosage of medication you have on hand which always assumes the denominator position of the problem. The medication is usually available per cc or ml, tablet or capsule which likewise always assumes the numerator position of the problem.

$$\frac{500 \text{ mg}}{1} \times \frac{\text{cc/ml, tablet or capsule}}{\text{dosage on hand}}$$

or from the example above

$$\frac{500 \text{ mg}}{1} \times \frac{\text{ml}}{5/6 \text{ gr}} \quad (2\text{nd component added to the problem})$$

The answer you are looking for needs to be in ml's, therefore you need to cancel out all other information in the problem. Since mg and gr are not like components, you need the third component of the problem - the conversion factor.

$$\frac{500 \text{ mg}}{1} \times \frac{\text{ml}}{5/6 \text{ gr}} \times \frac{1 \text{ gr}}{60 \text{ mg}} \quad (3\text{rd component added to the problem})$$

At this point, you are most likely asking yourself why the 1 gr is in the numerator and the 60 mg in the denominator positions? The answer is that you must set the problem up so that you can cancel out the unwanted categories. If you can't cancel out the unwanted categories, then you must have your conversion factor set up wrong.

Now, you are ready to work the problem. Remember to cancel like components from the numerator portion of the problem that matches the denominator portion of the problem. That includes zeros, if you can cancel 2 or 3 zeros from the numerator portion of the problem and 2 or 3 zeros from the denominator portion of the problem - great! Just remember you must cancel the same number of zeros from each portion of the problem.

$$\frac{500 \text{ mg}}{1} \times \frac{\text{ml}}{5/6 \text{ gr}} \times \frac{1 \text{ gr}}{60 \text{ mg}} = \frac{50}{5/6 \times 6} = \frac{50}{30/6} = \frac{50}{5} = 10 \text{ ml}$$

Great!

Try another one.

Doctor orders Phenobarbital 0.5 gr. On hand you have 15 mg per tablet. How many tablets are you going to give?

Doctor orders:

$$\frac{0.5 \text{ gr}}{1} \quad (1\text{st component})$$

Dosage on hand:

$$\frac{0.5 \text{ gr}}{1} \times \frac{\text{tablet}}{15 \text{ mg}} \quad (2\text{nd component added})$$

Conversion needed: 1 gr = 60 mg

$$\frac{0.5 \text{ gr}}{1} \times \frac{\text{tablet}}{15 \text{ mg}} \times \frac{60 \text{ mg}}{1 \text{ gr}} = \frac{0.5 \times 60}{15} = \frac{30}{15} = 2 \text{ tablets}$$

Got the hang of it?

Let's try a more difficult problem.

Doctor orders Chloral Hydrate 15 gr. On hand you have 500 mg per dram. How many ml's will you give?

Doctor orders:

$$\frac{15 \text{ gr}}{1} \times \frac{\text{dram}}{500 \text{ mg}} \times \frac{60 \text{ mg}}{1 \text{ gr}} \times \text{oops, need to get rid of that dram...}$$

$$\frac{15 \text{ gr}}{1} \times \frac{\text{dram}}{500 \text{ mg}} \times \frac{60 \text{ mg}}{1 \text{ gr}} \times \frac{5 \text{ ml}}{\text{dram}} = 15 \times 6 \times 5 =$$

$$\frac{450}{50} = 9 \text{ ml}$$

Amazing!

How about a little different problem?

As nurses, you must be able to work with IV pumps and set them according to your Doctor's order.

How about a Heparin problem, since Heparin must be on a pump for infusion.

Doctor orders 1500 units of Heparin per hour. On hand you have a 25,000 unit vial of Heparin and a 500 ml bag of Normal Saline to add the Heparin to. How many ml per hour will you set your pump?

Doctor orders:

$\frac{1500 \text{ units}}{\text{hour}}$ A little different because the Doctor ordered a specific amount of time.

$$\frac{1500 \text{ units}}{\text{hour}} \times \frac{500 \text{ ml}}{25,000 \text{ units}} = \frac{150 \times 5}{25} = \frac{750}{25} = 30 \text{ ml/hr}$$

The second concept is used with general IV mathematical problems. This concept includes:

First Component - The Doctor's Order

Second Component - Tubing Size or Drop Factor (gtt/ml)

Third Component - Conversion Factor (1 hr = 60 min.)

This same principal works terrific with the calculation of IV problems with only a slightly different twist.

$$\frac{\text{Dr order}}{\text{hr}} \times \frac{\text{gtt}}{\text{ml}} \times \frac{1 \text{ hr}}{60 \text{ min}}$$

The Doctor's order is still the first component of the problem but the second component of the problem is now the size of the IV tubing you have available. Macro drip tubing is available 10, 15, or 20 gtt/ml or Microdrip tubing that is available in 60 gtt/ml.

Try a problem and it will make more sense.

Doctor orders 1000 cc D5W to infuse in 8 hours. The tubing you have available is a 10 gtt/ml set. How many gtt/min will you adjust your flow for?

1st component - Doctor's order specifically...

$$\frac{1000 \text{ cc}}{8 \text{ hr}} \times$$

2nd component - Tubing size...

$$\frac{1000 \text{ cc}}{8 \text{ hr}} \times \frac{10 \text{ gtt}}{\text{ml}}$$

3rd component - Conversion factor...

$$\frac{1000 \text{ cc}}{8 \text{ hr}} \times \frac{10 \text{ gtt}}{\text{ml}} \times \frac{1 \text{ hr}}{60 \text{ min}} = \frac{1000}{8 \times 6} = \frac{1000}{48} = 20.8$$

or 21 gtt/min

Now, you may be wondering how and why 1 hr is the numerator and 60 min is the denominator. Same answer as before, you must set the problem up so that it will cancel out all unwanted information or categories.

Example:

Doctor orders 500 ml D5W to infuse over 12 hours. The tubing available is microdrip (60 gtt/ml). How many gtt/min will you adjust your flow rate for?

Doctor orders:

$$\frac{500 \text{ ml}}{12 \text{ hr}} \times \text{(1st component)}$$

$$\frac{500 \text{ ml}}{12 \text{ hr}} \times \frac{60 \text{ gtt}}{\text{ml}} \text{ (2nd component added)}$$

$$\frac{500 \text{ ml}}{12 \text{ hr}} \times \frac{60 \text{ gtt}}{\text{ml}} \times \frac{1 \text{ hr}}{60 \text{ min}} \text{ (Conversion factor added)}$$

Time to finish the problem...

$$\frac{500 \text{ ml}}{12 \text{ hr}} \times \frac{60 \text{ gtt}}{\text{ml}} \times \frac{1 \text{ hr}}{60 \text{ min}} = \frac{500}{12} = 41.66 \text{ or } 42 \text{ gtt/min}$$

How about something a little different?

Doctor orders 1000 cc D5W at 21 gtt/min. How many hours will it take to infuse? Your available tubing is 10 gtt/ml set.

This may look difficult, but follow the same principles.

Doctor orders:

$$\frac{1000 \text{ cc}}{1} \times \frac{10 \text{ gtt}}{\text{ml}} \times \frac{\text{min}}{21 \text{ gtt}} \times \frac{1 \text{ hr}}{60 \text{ min}} = \frac{1000}{21 \times 6} = \frac{1000}{126}$$

= 7.9 or 8 hr.

Remember everything is set up within the problem to cancel. If you are having trouble canceling, then you do not have your conversion factors in the right positions.

How about some really difficult problems?

The Doctor orders 2 mg of medication per kg of body weight. On hand you have a bottle that reads 0.5 gm/5 ml. Your patient weight 50 pounds. How many ml's will you give?

Doctor orders:

$$\frac{2 \text{ mg}}{\text{kg}} \times \frac{5 \text{ ml}}{0.5 \text{ gm}} \times \frac{1 \text{ gm}}{1000 \text{ mg}} \times \frac{1 \text{ kg}}{2.2 \text{ lb}} \times \frac{50 \text{ lb}}{1} =$$

$$\frac{2 \times 5 \times 5}{0.5 \times 100 \times 2.2} = \frac{50}{110} = 0.45 \text{ or } 0.5 \text{ ml}$$

The problem really didn't change much. You still must set up the problem to cancel out unwanted categories. Doctor's order and dosage on hand still remained the first and second component of the problem. It was just necessary to add in the conversions and the weight of the patient.

And now, the ultimate of problems! The ICU mathematical problem. This is the concept used with mcg/kg/min problems. This concept includes:

- First Component - mcg/kg ordered by the Doctor
- Second Component - Patient's weight/min
- Third Component - Dosage of Medication available
- Fourth Component - Conversion Factors

The Doctor orders Dobutrex 6 mcg/kg/min to infuse IV to sustain the blood pressure of a patient weighting 165 lb. The solution available is 250 mg in 1000 ml of D5W. Calculate the ml/hr to set the IV pump.

OK, let's begin at the beginning.

Doctor orders:

$$\frac{6 \text{ mcg}}{\text{kg}} \times \text{Wait a minute, what do you do with that minute?}$$

Remember the first component of the problem is mcg/kg.

The second component of the problem is the patient's weight/min. To allow for canceling, the patient's weight becomes the numerator (always) and the minute becomes the denominator (always). OK, let's continue.

$$\frac{6 \text{ mcg}}{\text{kg}} \times \frac{165 \text{ lb}}{\text{min}} \times \frac{1000 \text{ ml}}{250 \text{ mg}}$$

At this point you will notice that the third component of the problem has been added - the dosage of medication available. Now add the fourth component of your problem - the conversion factors necessary to cancel the unwanted categories and complete the problem.

$$\frac{6 \text{ mcg}}{\text{kg}} \times \frac{165 \text{ lb}}{\text{min}} \times \frac{1000 \text{ ml}}{250 \text{ mg}} \times \frac{1 \text{ mg}}{1000 \text{ mcg}} \times \frac{60 \text{ min}}{\text{hr}} \times \frac{1 \text{ kg}}{2.2 \text{ lb}}$$

$$= \frac{6 \times 165 \times 6}{25 \times 2.2} = \frac{5940}{55} = 108 \text{ ml/hr}$$

Well, that about wraps it up. Dimensional analysis is a great way to calculate medication problems and it only takes a little practice to really get the hang of it. So...keep practicing.

NURSING MATH SIMPLIFIED
Practice Problems
Concept #1

1. Dr. orders 250 mg. On hand 0.5 gm per tablet. How many tablets will you give?
2. Dr. orders Morphine $\frac{1}{6}$ gr. On hand you have $\frac{1}{4}$ gr per ml. How many ml's will you give?
3. Dr. orders Atropine $\frac{1}{150}$ gr. On hand is 0.4 mg per ml. How many ml's will you give?
4. Dr. orders Lanoxin 40 mcg IM. On hand you have 0.1 mg per ml. How many ml's will you give?
5. Dr. orders Tigan 0.2 gm IM. On hand is 100 mcg per ml. How many ml's will you give?
6. Dr. orders Morphine $\frac{1}{24}$ gr. On hand is $\frac{1}{8}$ gr per minim. How many ml's will you give?
7. Dr. orders Thorazine 10 mg PO. On hand is $\frac{1}{6}$ gr tablets. How many tablets will you give?

8. Dr. orders elixir of Phenobarbital 30 mg PO. Stock is 1 gr per dram. How many ml's will you give?
9. Dr. orders Noctec 0.5 gr PO HS PRN. On hand 500 mg per dram is available. How many ml's will you give?
10. Dr. orders Lanoxin elixir 90 mcg PO BID. On hand is 0.05 mg per ml. How many ml's will you give?

NURSING MATH SIMPLIFIED
Practice Problems
Concept #2

1. Dr. orders 800 ml of D5W to infuse in 8 hrs. The IV tubing set is 15 gtt/ml. How many gtt/min?
2. Dr. orders 2000 ml to infuse over 16 hrs. The IV tubing set is 10 gtt/ml. How many gtt/min?
3. Dr. orders 500 ml NS to infuse in 8 hrs. The IV tubing set is 60 gtt/ml. How many gtt/min?
4. Dr. orders Ringers Lactate 500 ml to infuse in 5 hrs. IV tubing set available is 10 gtt/ml. How many gtt/min?
5. 1200 ml D5W is ordered to infuse in 10 hrs. IV tubing set is 20 gtt/ml. How many gtt/min?
6. Administer 150 ml over 3 hrs. Microdrip tubing 60 gtt/ml is available. How many gtt/min?
7. You are to administer 50 ml of an IV antibiotic in 15 min. IV tubing is 10 gtt/ml. How many gtt/min?

8. Infuse 150 ml Gentamicin via IVPB over 1 hour. IV set is 10 gtt/ml. How many gtt/min?

9. 1200 ml to infuse in 10 hrs. IV set is 20 gtt/ml. How many gtt/min?

10. The order is NS 500 ml/4 hrs. IV set is 15 gtt/ml. How many gtt/min?

NURSING MATH SIMPLIFIED
Practice Problems
HEPARIN

1. Dr. orders 900 units of Heparin to infuse per hour. Available you have premixed Heparin 25,000 units in 500 cc D5W. How many cc/hr will you set your IV pump?
2. Dr. orders Heparin 1500 units per hr. The solution available is 20,000 units in 1000 cc D5W. How many ml/hr will you set your IV pump?
3. The Doctor orders a patient to receive 1000 units of Heparin hourly from a solution of 20,000 units in 500 ml D5NS. How many ml/hr will you set your IV pump?
4. Doctor orders 1200 units of Heparin per hour. The solution is available 35,000 units Heparin in 1000 cc. How many ml/hr will you set the IV pump?
5. Doctor orders 1500 units Heparin per hour. The solution infusing is 25,000 units in 1000 cc. How many ml/hr is infusing?

NURSING MATH SIMPLIFIED
Practice Problems
Concept #3

1. Dr. orders Dopamine 400 mg in 250 cc at 5 mcg/kg/min. Your patient weighs 200 pounds. Set your pump for ml/hr.
2. Dr. orders Nipride 50 mg in 250 cc at 1 mcg/kg/min. Your patient weighs 160 pounds. Set your pump for ml/hr.
3. Dr. orders Inocor mixed 100 mg in 100 cc at 5 mcg/kg/min. Your patient weighs 160 pounds. Set your pump for ml/hr.
4. Dr. orders Nipride 50 mg in 250 cc at 2 mcg/kg/min. Your patient weighs 250 pounds. Set your pump for ml/hr.
5. Start Dopamine at 5 mcg/kg/min. Solution available is 400 mg in 250 cc. Your patient weighs 110 pounds. Set your pump for ml/hr.

APPENDIX 7
Math Research
Quizzes 1-4

1. Order: Phenobarbital 0.3 gm
The bottle is labeled: Phenobarbital 130 mg/ml
How many ml's will you give?
2. Order: 750 cc of Normal Saline to infuse over 4 hours
Drop Factor: 15 gtt/ml
Calculate the flow rate in gtt/min.
3. Order: Nipride 3 mcg/kg/min
The patient weighs: 165 lb
Supply: 250 cc D5W with 50 mg of Nipride
Calculate ml/hr to set the IV pump.

MATH RESEARCH
Quiz #2

Date: _____

Identification Number: _____

Calculate the following problems and show your computation for each problem. Calculators may be used. A conversion table is provided.

1. Order: Heparin 1500 units/hr
Supply: 500 cc D5W with 25,000 units of Heparin
Calculate ml/hr to set the IV pump.

2. Order: Dobutamine 10 mcg/kg/min
The patient weighs: 143 lb
Supply: 500 ml D5W with 250 mg of Dobutamine
Calculate ml/hr to set the IV pump.

3. Order: Morphine 5 mg
The bottle is labeled: Morphine 1/6 gr/ml
How many ml's will you give?

MATH RESEARCH
Quiz #3

Date: _____

Identification Number: _____

Calculate the following problems and show your computation for each problem. Calculators may be used. A conversion table is provided.

1. Order: 1000 ml D5W to infuse at 20 gtt/min
Drop Factor: 15 gtt/ml
Calculate how many hours it will take for the IV to infuse.

2. Order: Atropine 0.6 mg
The bottle is labeled: Atropine 1/150 gr/ml
How many ml's will you give?

3. Order: 3000 ml D5W to infuse over 24 hours
Drop Factor: 10 gtt/ml
Calculate the flow rate in gtt/min.

MATH RESEARCH
Quiz #4

Date: _____

Identification Number: _____

Calculate the following problems and show your computation for each problem. Calculators may be used. A conversion table is provided.

1. Order: Regular Insulin 2 units/hr
Supply: 500 ml NS with 40 units of Regular Insulin
Calculate ml/hr to set the IV pump.

2. Order: Digoxin 100 mcg
The bottle is labeled: Digoxin 0.5 mg/2 ml
How many ml's will you give?

3. Order: Vancomycin 3 mg/kg
The patient weighs: 75 kg
The bottle is labeled: 0.3 gm/ml
How many ml's will you give?